The Liquid Argon Jet Trigger of the H1 Experiment at HERA

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The Liquid Argon Jet Trigger, installed in the H1 experiment at HERA, implements in 800 ns a real-time cluster algorithm by finding local energy maxima, summing their immediate neighbors, sorting the resulting "jets" by energy, and applying topological conditions. It operated since the year 2006 and drastically reduced the thresholds for triggering on electrons and jets.

1. Introduction

After the luminosity upgrade of the HERA machine in the years $2000-2001$ (HERA-2), a significant increase of the background rates was expected and indeed observed. While parts of the H1 detector were upgraded during the year 2001 as well, the H1 data logging rate to permanent storage (about 10 Hz) remained a stringent constraint for the data acquisition system. The aim of the upgrade of the digital part of the LAr trigger, the Jet Trigger [1], was to complement the existing global LAr calorimeter trigger with a system that performs real-time clustering to avoid summing-up noise distributed over large parts of the calorimeter, thus allowing for triggers on even lower energy depositions while keeping the trigger rates within the required bounds.

2. Jet Trigger Algorithm

The Jet Trigger identifies the localized energy depositions of electrons, photons and bundles of hadrons in the LAr calorimeter, and uses these energy clusters ("jets"), including their topological information, for a fast event selection. The "jets" are found by identifying trigger towers with a local energy maximum. Around this maximum the immediate neighboring towers are summed and added to the center. The resulting local "jets" are the basis of the trigger decision. Such a local concept improves the sensitivity for low-energy depositions in the calorimeter. The "jets" are then sorted by energy in decreasing order. The 16 highest energy "jets" are used to provide flexible and optimized triggers based on discrimination of individual jet energies, counting jets with energies above certain thresholds, and determination of topological correlations between the jets.

3. Jet Trigger Realization

The realization of the above algorithm was implemented in the following way. The input of the jet trigger is 1200 analog trigger towers received at the 10 MHz HERA bunch crossing rate. The clock generation is performed by a Clock Distribution and Configuration Card with adjustable phases to minimize the overall system latency. The ADC-Calculation-Storage unit (see figure 1) digitizes the 1200 input towers to 8 bit accuracy each, transforms the energies into transverse energies, and sums the electromagnetic and hadronic energies. The resulting 440 outputs are transferred via a bit-serial link to the so-called Bump Finder Unit (see figure 2). This unit searches for local maxima of energy and sums them with their immediate neighbors. This search and summing is done, for each input tower, in a completely parallel fashion. The resulting 116 energy maxima are sorted by decreasing energy first quadrant-wise, then detector-wise, by the Primary and Secondary Sorting Units. The programmable Trigger Element Generator (see figure 3) applies conditions on the 16 highest energies and their locations. These conditions are local (energy and polar angle criteria on each individual jet, azimuthal and polar angle differences between jets), and global (total energy and missing energy in the event).

In total, the Jet Trigger consists of about 550 FPGAs with 75 M Gates, computing 300 G operations/s. The 12 GB/s raw data rate is reduced to 16 trigger element bits per bunch cross, corresponding to a data reduction factor of 600. Each unit performs its function within 1 to 3 bunch crossings. The total latency is 800 ns.

4. Jet Trigger Results

The Jet Trigger operation started in the summer of 2006 and accumulated about 100 pb^{-1} of luminosity until the end of the HERA−2 program in July 2007. It opened the phase space for events containing a single forward jet of at least 8 GeV at low angle below 30 degrees. The energy-sorted jet information was combined with track-based triggers to successfully perform b-tagging with a track threshold of 1.5 GeV. The Jet Trigger was used to successfully decrease the electron triggering threshold from 6 GeV down to 2 GeV (see figure 4) and to perform the world's first measurement of the longitudinal structure function F_L of the proton.

References

[1] A. Dubak, AIP Conf. Proc. **899** (2007) 573.

Figure 1: Details of the installed hardware in the electronic trailer of the H1 experiment: View of the Jet Trigger ADC-Calculation-Storage unit composed of 8 crates, one for each of the 8 octants of the LAr calorimeter. The system receives the analog trigger towers and transfers the digitized signals to the Bump Finder Unit via a bit-serial link.

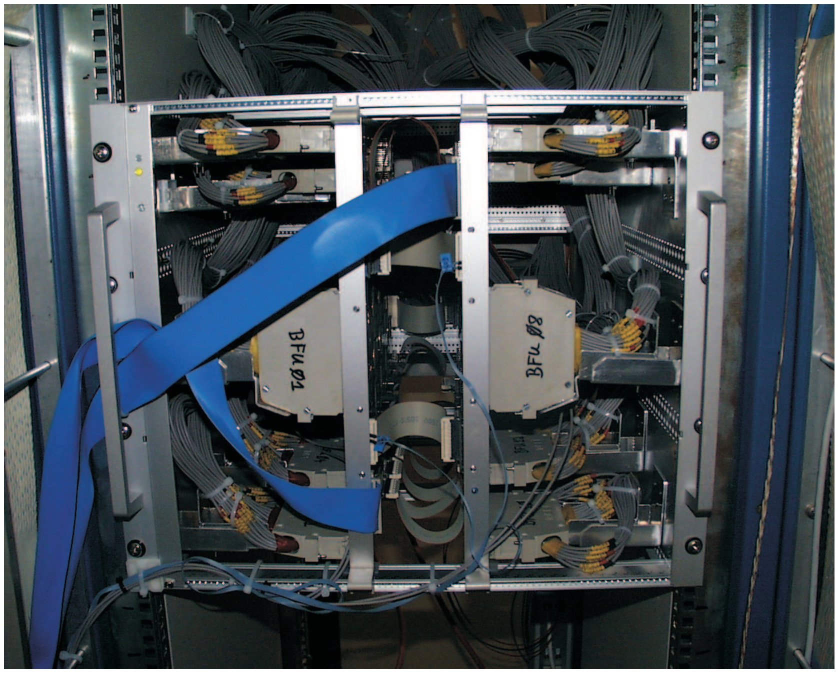

Figure 2: View into the Bump Finder crate containing 2 units, one for each calorimeter hemisphere. In the Bump Finder unit the “jets” are found in real-time. The Primary Sorting Unit presorts the jets from one quadrant according to their energies and sends its output to the Secondary Sorting Unit.

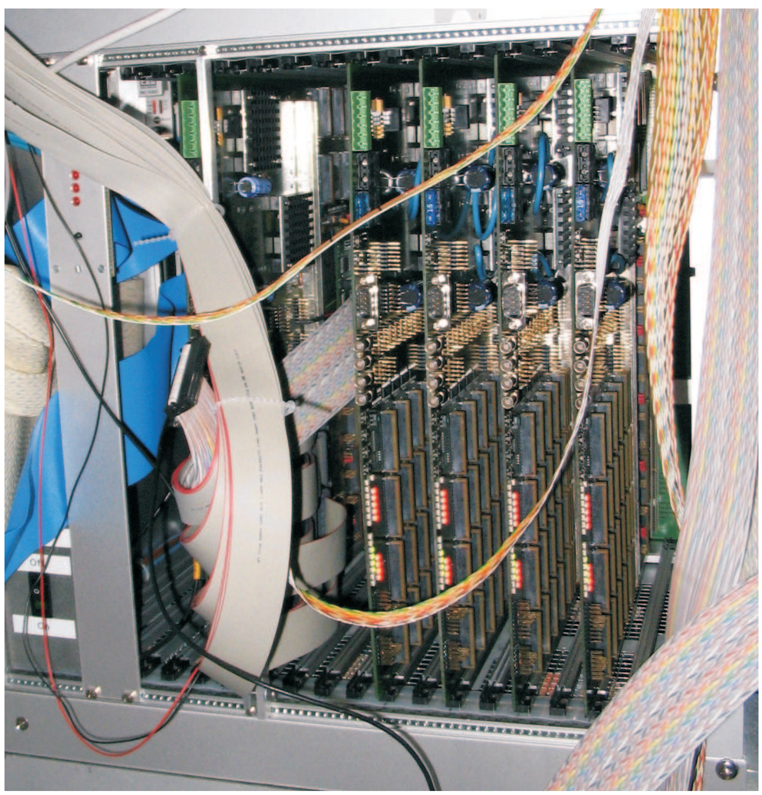

Figure 3: View into the crate housing the Secondary Sorting Unit and the 4 Trigger Element Generator units. In the Secondary Sorting Unit the presorted lists from the four quadrants are finally sorted by energy and transferred to the Trigger Element Generator units which apply topological conditions to the jets.

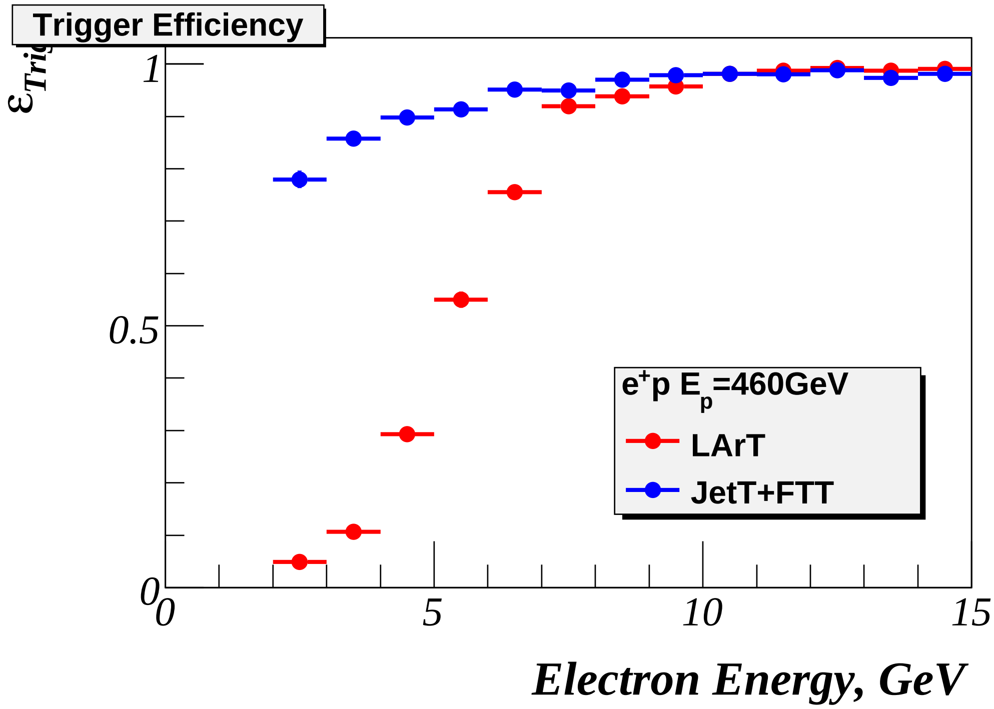

Figure 4: Efficiency to trigger on electrons as a function of the electron energy for both the “old” LAr trigger (red) and the Jet Trigger (blue). Note the decrease of efficient triggering from 6 GeV to 2 GeV.